

Conserving and Managing the Biodiversity of Malawian Farm Animal Genetic Resources – A Case of Malawi Zebu cattle

Mizeck G.G. Chagunda¹ and Clemens B.A. Wollny²

¹*Department of Animal Science, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi,*

²*Institute of Crop and Animal Production in the Tropics, Georg-August-University of Goettingen, Germany*

INTRODUCTION

At breed level, farm animal genetic resources (FAnGR) are genetically unique populations formed throughout all domestication processes with each animal species used for production of food and agriculture. In Malawi, FAnGR constitute an important sub sector within agriculture, contributing about 7% of the total Gross Domestic Product (GDP), and about 20% of the value of total agriculture products (NLDMP, 1998). Indigenous breeds, which are part of the farm animal genetic resources, have over time developed special adaptive traits that enable them live and produce under the existing conditions. These traits include resistance to specific diseases, heat tolerance, ability to use poor quality feeds and to survive with little and/or irregular supply of feed and water. These specifically adapted breeds facilitate introduction of livestock agriculture in areas where exotic breeds cannot survive or optimally produce (Rege, 1995). The population of cattle in Malawi is estimated at 618,800 of which 95.2% are owned by small-scale rural farmers and the rest by large scale commercial farmers in estates and peri-urban areas (NLDMP, 1998). The Malawi-Zebu, which is predominantly a beef animal and naturalized indigenous breed, constitutes about 97% of the cattle population and has several phenotypes with varied origin (Butterworth and McNitt, 1994; Jere and Msiska, 2000). The following three distinct phenotypes have been reported: (i) The Angoni Zebu, which has big ears, large stature and long horns. Predominantly spread in the northern region (ii) short-horned Malawi Zebu, which is small in stature and distributed in central and southern regions of Malawi and (iii) the Nkone-like Malawi Zebu, owned by the Ngonis of Mzimba, Dedza and Ntcheu districts (Jere and Msiska, 2000). These putative genotypes have, however, not been supported by DNA research to ascertain whether they are indeed distinct stocks or not, as is argued by

Butterworth and McNitt (1994) that their distances are relatively insignificant (Ambali et al., 2001).

The animal species important today for food and agriculture production are a consequence of processes of domestication that have been continuing for almost 12,000 years. Animal genetic diversity allows farmers to select stocks or develop new breeds in response to environmental change, threats of disease, new knowledge of human nutrition requirements, changing market conditions and societal needs, all of which are largely unpredictable. What is predictable is the future human demand for food. At the recent rate of population growth, during the second decade of this century, it is predicted that the consumption of food and agriculture products will be equivalent to that in all the last 10,000 years. This need will be felt most acutely in developing countries where 85 percent of the increases food demand is expected (FAO, 2000). Conservation of domestic animal diversity is the sum total of all operations involved in management of animal genetic resources, such that these resources are best used and developed to meet immediate and short-term requirements for food and agriculture, and to ensure the diversity they harbour remains available to meet possible long-term needs. Conservation can be *insitu* or *ex-situ*. In-situ conservation is the active breeding of animal populations for food production and agriculture, such that the diversity is both best utilized in the short term and maintained for the long term. Operations pertaining to insitu conservation include performance recording schemes and development (breeding) programmes. Insitu conservation also includes ecosystem management and use of FanGR for the sustainable production of food and agriculture.

WHY CONSERVE FARM ANIMAL GENETIC RESOURCES?

Breed development in most developing countries is characterized by the introduction of exotic breeds with a resultant shift to commercial production focused on a few major traits. The competitiveness of the indigenous breeds has been a decisive factor for their survival. Actual or perceived low performing breed have a disadvantage in developed and developing markets. Performance data, however, do often not include lifetime efficiency in the prevailing production system. Indigenous livestock populations are

often considered as inferior. Impatience to develop appropriate selection schemes and lack of breeding goals have resulted in numerous cross breeding programmes or breed replacement strategies with exotic breeds. With the globally emerging trend towards one breed per species the situation for small populations becomes critical (Wollny, 1995).

The major reasons for conservation of FAnGR are:

- ❑ Economic: Genetic variation is the raw material for any livestock improvement. As such then, conservation will maintain and promote genetic variation hence providing options for the future.
- ❑ Scientific: DNA sequences responsible for the expression of specialized physiological and adaptive functions are not yet utilized. Conservation provides the potential for these traits to be expressed and utilized.
- ❑ Cultural and social: Livestock is part of civilization, human culture and world heritage. Farm animal, wildlife and plant genetic resources are equal major components of global biological diversity.
- ❑ Development and sustainability: Sustainable development of animal agriculture is based on sustainable use of FAnGR. Conservation and development are parts of one process. The farmer in the developing country deserves full support to obtain the best information on the locally available animal genetic diversity.

Malawi Zebu, one of the farm animal genetic resources of Malawi have not been fully characterized hence most of their unique attributes are not fully known. For this and the reasons indicated above, Malawi Zebu cattle need to be conserved. However, if care is not taken, Malawi Zebu just like other indigenous animals can face risk of loss and in extreme cases extinction. The following are some of the factors that can lead to the risk of loss and extinction of farm animal genetic resources.

FACTORS CAUSING RISK OF LOSS AND EXTINCTION OF BREEDS

Given the fact that domestic animal diversity is critical for food security, it is important not to permit the erosion of this diversity. However, there are some factors that predispose breeds to the risk of extinction. Some of the major factors are: population

size, change in farming systems, cross breeding, reproductive inefficiency, and lack of breed societies, which are discussed as follows:

Population size

From a genetics point of view, a population is not just a group of individuals, but also a breeding group (Falconer, 1989). Genetics of a population therefore, is concerned not only with the genetic constitution of the individual but also with the transmission of the genes from one generation to the next. The risk to lose a certain gene increases dramatically in small populations. The principle effect of reduced population size is the associated decline in intra locus genetic variability within individuals (heterozygosity). This in turn is measured as the inbreeding coefficient. Many studies have shown that functional traits deteriorate by 3% to 5% for every 10% increase in the inbreeding coefficient. In a random mating population of N individuals, with equal number of males and females and discrete generations, the increase in inbreeding per generation is a simple function of the population size: $1/(2N+1)$. However, domestic livestock populations do not mate randomly, and they usually have many more breeding females than males. In these circumstances, the “effective population size” N_e is usually much lower than the number of animals in the population: $N_e = 4MF/(M+F)$, where M and F are the numbers of males and females, respectively (Cunningham, 1995).

For some time now Malawi Zebu has always been considered to be one population comprised of one genotype. However, recent results from the work by Ambali et al. (2001) utilizing micro satellite genetic markers on certain specific loci, indicate that Malawi Zebu is comprised at least three different genotypes. These genotypes are geographically located in different areas indicating different sub-populations of Malawi Zebu existing within Malawi. Knowing that the total cattle population in Malawi is small as is estimated at 807,700 (Malawi Government, 1996), it translates that the size of each one of these sub-populations is even smaller. This increases the threat of inbreeding. The danger is that these pockets of different genotypes of Malawi Zebu have not yet been fully characterized hence their different and unique attributes are not yet fully known. In which case any loss of genes leads to losing what is not known i.e. any risk of loss is associated with a high degree of uncertainty.

Change in farming systems

Change in farming system often involves changed breeding objectives for livestock (Cunningham, 1995). In traditional systems, number of livestock rather than output per head is often the main consideration. In these circumstances, traits related to survival in the face of nutritional, health, and climatic stress predominate. As farming systems become more market oriented, volume and value of saleable product takes over and selection goals often change from multi-purpose use to much narrower targets. The selection goals shift to such traits as prolificacy, early maturity, individual growth rate and milk yield, and aspects of milk composition and meat quality. Selection for such traits transforms the genetic constitution of the breed and also promotes inter-population gene flow through migration and crossbreeding.

Economic and demographic pressures cause changes in farming systems. These pressures are generally for intensification of systems. At a very broad level, this can be quantified by comparing annual rates of growth in the numbers of animals on the one hand, and of volume of production on the other (Cunningham, 1995). In Malawi, more than 80% of the human population are involved in the smallholder subsector, which is primarily subsistence. About 11% of the people are in the estates (Malawi Government, 1996). The majority of smallholder farmers have very limited land available to them. Three categories Malawian smallholder farmers can be distinguished. The first group comprises 35% with farms of less than 0.7 hectares that can only yield a household subsistence. The second group is that with farms between 0.7 and 1.5 hectares producing enough of the subsistence requirement and occasional cash income from sale of farm produce. These comprise 40% while the rest 25% operate holdings larger than 1.5 hectares and are involved in some commercial agriculture. As a result of this land shortage, the only means of increasing production is through intensification and integration of crops and livestock (ICLARM and GTZ, 1991).

Crossbreeding

The breeds native to particular countries or localities are often well adapted to the local conditions – climate, nutrition, disease exposure and so. The breeds are rarely thought to

be perfect in all respects and improvements in productivity are desired. One of the most rapid ways of making genetic change is to introduce of the characteristics of a new breed by crossing it with the indigenous breed. For any one pair of genes, the two alleles present in a cell may be the same (homozygous) or different (heterozygous). The two alleles are likely to differ in the strength of their effect on the characteristic they are helping to control. It is a basic presumption of animal breeders that – for at least a proportion of genes carried by breeds – different breeds are likely to carry alleles (affecting the same trait) in different frequencies, possibly to be homozygous for different alleles. Crosses between different breeds are likely, therefore, to have a larger proportion of heterozygous gene combinations than the parental breeds -. - The chance to lose an existing specific and unique gene combination within an indigenous population, therefore, increases through crossbreeding, which are often introduced as improvement programmes. Indiscriminate crossbreeding and continuous substitution of indigenous breeds has been identified as one of the major threats to the conservation of indigenous breeds (Wollny 2001).

In a crossbreeding programme, Mwale et al. (1999) found that there are dependencies between genotype and management level under smallholder conditions. The genotypes were Malawi Zebu, Holstein Friesian, and Malawi Zebu x Holstein Friesian crosses of different grades. When assumed labour costs were included in the gross margin analysis, Holstein Friesian was the profitable genotype to raise. However, when no labour costs are included in the analysis (a situation reflecting the practical reality of the majority of the farmers involved), the Malawi Zebu cow was the most efficient genotype for local milk production in a low-input low output system. The authors concluded, that under the given production environment the indigenous Malawi Zebu should be maintained and utilized as a genetic resource. These early findings of the relative higher efficiency of an indigenous breed in a given production system are supported in recently published results questioning the superiority of some crossbreeding programmes for dairy cattle in Kenya (Karugia et al. 2001) and for goats in Ethiopia (Ayalew 2000).

Reproductive inefficiency

In the productive lifetime of any individual animal, there is an expected number of progeny that that animal can produce. Productive lifetime being the period between first calving and culling is the effective period in as far as reproduction is concerned. This being the case productive lifetime is breed specific and at times production system specific and is mainly dependent on fertility or reproductive traits. Traits like age at first calving, number of inseminations per conception, gestation period, calving interval, play a very vital role on determining the productive lifetime of any individual cow. In bulls, their general fertility and fecundity determines the number of progeny that the individual will leave in the population after being culled.

The rearing practice of Malawi Zebu cattle is mostly to let them graze in the communal wetland area locally called *Dambo*. The only time Malawi Zebu cattle are confined is when they are either being stall-fed for beef or they are used for intensive dairy production. In the event that there are no or insufficient bulls in the population, cows lose their heat without being served. This is reproductive waste. The other time when there is high reproductive wastage is the period when most of the cows in the herd are on heat at the same time. Even when the male-female ratio in the herd could be what is referred to as normal (4 to 10% of the herd being bulls), in such events the bulls become inefficient. In a study carried out in Central Malawi by De Koning, 1977, 85% of all calvings occur between April and September (i.e. during the dry season), with 56% concentrated in June, July and August. These results show that there is a distinct breeding season between July and December with the highest fertility falling between September and November. Estrus (heat) seems to occur most frequently in cows when minimum temperatures are high and atmospheric humidity is low. With the foregoing, it is important that farmers optimally utilize the breeding season and breed their animals when sexual activity in the cows is high.

Under traditional management, the Malawi Zebu heifer tends to calve for the first time at approximately three years of age and, if she fails to do this, she will not calve down until she is approximately four years old. Delays in breeding the heifers in time leads to short productive lifetime even though the animals may be in the herd much longer and may not

contribute effectively to the progeny generation. Wollny et al.(1998) reported average ages at first calving of 49.8 (SD 9.0) and 50.9 (SD 12.0) months for Malawi Zebu kept on state owned breeding stations.

Lack of breed societies

Breed societies are the keepers and developers of two valuable resources –first, the breeds they represent and second, the people associated with them. Breed society is a farmers organization whose ‘Board of Directors’ are livestock farmers while management and operations are carried out by technical experts. Traditionally, breed societies are the “pedigree houses” where their main functions include: a) maintenance and management of the herd book, b) marketing of breeding stock, c) selection of breeding stock, and d) organization of animal shows. Increasingly breed societies are being structured around the computer. Maintaining databases and analyzing them with modern techniques has become the order of the day. By and by breed societies have had to redefine their roles in order to survive in today’s tough economic climate, and for them to help members remain profitable levels of production. Breed societies are these days heavily involved in adding value to their breeds by making known the actual and perceived benefits of their particular breeds versus breeds. This is done through marketing and promotion, hence conservation by utilization. Table 1 shows some selected indigenous breeds and their societies in Southern Africa.

Table 1: Some selected indigenous breeds and their societies in Southern Africa

Breed	Country	Breed Society
Africaner	South Africa	The Africaner Cattle Breeders’ Society of South Africa
Drakensberger	South Africa	The Drakensberger Cattle Breeders’ Society
Nguni	South Africa	The Nguni Cattle Breeders’ Society
Tuli	South Africa	Tuli Cattle Breeders’ Society of South Africa
Tuli	Zimbabwe	Tuli Cattle Society of Zimbabwe

Although several livestock-farmer associations currently exist in Malawi, none of them assumes the duties of a breed society. There is no herd book and no systematic

recording - exists. There is no - breeding programme and the breeding policy for almost all livestock species is hazy. As a result the Malawi Zebu is currently not –subject to sustainable genetic improvement, marketing and promotion as other indigenous breeds like Tuli, Nguni, and others in the nearby countries in the southern Africa region. -

THE CHALLENGES AHEAD

Lack of suitable animal breeding infrastructure, the relatively small population, little exchange of breeding stock, the absence of breed societies and stud breeders are some of the major set-backs in the improvement of indigenous cattle in Malawi. Indiscriminate and uncontrolled crossbreeding pose a threat to any sustainable conservation programme for Malawi Zebu.

Performance data for estimation of breeding values are not available and characterization information is incomplete. This is because there is no performance recording system in place. If any records are available, they are used -to control management and feeding of animals on the farms. Use of records in the long term, analysis of such records will lead to genetic improvement of the animal population. Many recording organizations in developed countries have shown that the participating farmers are able to increase productivity and genetic merit of their animals and raise the quality of their produce. It is also possible to monitor the changes in productivity. Since even within the smallholder farmer sector, the farms are not homogeneous in nature, animal production characterization (minimum input/maximum output/highest precision) can best be organized by recording performance data under different intensities and under - controlled conditions, (Bruns, 1995), without necessarily compromising the accuracy important for developing strategies for further improvement. In the area of performance recording one of the challenges is that it is difficult to motivate smallholder farmers to participate in animal recording programs.

Table 2 summarizes some major constraints affecting the genetic improvement of Farm Animal Genetic Resources in Malawi.

TABLE 2: Major constraints for genetic improvement of Farm Animal Genetic Resources in Malawi

<p><i>Agricultural Sector policy</i></p> <ol style="list-style-type: none"> 1. Insufficient of national breeding policies 2. Prevailing cattle theft not under control 3. Lack of well defined breeding strategies 4. Insufficient conservation strategies for FAnGR established or implemented 5. Non-sustainable of continuity of breeding programmes 6. Several un-coordinated and externally funded programmes for livestock improvement 7. Insufficient enabling policies supporting participatory livestock development 8. Non existence of studies quantifying the contribution of Malawi Zebu cattle to food security and sustainable livelihoods in Malawi 9. -
<p><i>Infrastructure</i></p> <ol style="list-style-type: none"> 1. Lack of adequate performance recording scheme 2. Non-existence of breeders organizations 3. Insufficient number of qualified animal breeders <p>Communication, transport and computation facilities insufficient</p>
<p><i>Breeding programmes</i></p> <ol style="list-style-type: none"> 1. Non defined breeding objectives 2. Inefficient sire exchange and artificial insemination (A.I.) programme 3. Small population size and unreliable animal identification 4. Insufficient phenotypic and genetic characterization 5. Indigenous breeds not perceived as a valuable asset
<p><i>Selection and genetic gain</i></p> <ol style="list-style-type: none"> 1. Long generation intervals through extended and late maturing animals 2. Low selection intensity through low reproductive performance, high mortality rates and limited capacity for on farm performance testing 3. Lack of records for estimated breeding values

- | |
|---|
| <ol style="list-style-type: none">4. Inbreeding effects may result in decreasing performance5. Assumed antagonistic relationship between genetic merit for production and adaptation |
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Source: modified after Wollny (1995)

BREEDING STRATEGIES

In a competitive market, a breed or population survives only if it is superior in at least one trait of economic relevance. Indigenous breeds have emerged in specific natural habitats and production systems over time. Unfortunately, little is known about the adaptive value of such populations and their functional role in crop-livestock production systems. It is therefore obvious that the most promising strategy for the conservation of FAnGR should focus on utilization and improvement of indigenous populations. Socio-economic rather than genetic reasons seem to dictate the genotype raised by the smallholder farmers hence the breeding decisions for those genotypes. From the study by Nakhumwa et al. (2000), profitability (39.5%), ease of management (23.7%), and the dual purpose nature of the livestock (5.3%) were some of the reasons why smallholder farmers choose to raise particular livestock species. For some livestock types, more especially Malawi Zebu cattle farmers indicated that they inherited the animals. Since these socio-economic reasons are basically dealing with the production environment, considerable improvement could be achieved by improving the management of the indigenous farm animal genetic resources in Malawi.

For the smallholder and communal sector in southern African countries Wollny (1995) suggested an open nucleus scheme approach. A dispersed open nucleus breeding scheme may be an appropriate programme for the sustainable utilization of indigenous farm animal genetic resources in Malawi.

By definition, in a dispersed open nucleus scheme, the animals are not physically located in one place and there is allowance of inflow of foreign germplasm into the system (Lohuis, 1998). As compared to the centralized, closed nucleus scheme, the dispersed open nucleus scheme has the following advantages:

1. There is less threat from high inbreeding levels since the nucleus has no size limitations and the scheme is still open to some percentage of foreign germplasm.
2. The nucleus environment automatically reflects the production environment hence a very reduced (if any) rate of within-country genotype by environment interaction.
3. There is increased farmer participation since more farmers have direct impact on the breeding programme.
4. Farmers still own and control superior germplasm.
5. There is less demand for additional investment since there is high utilisation of existing infrastructure.

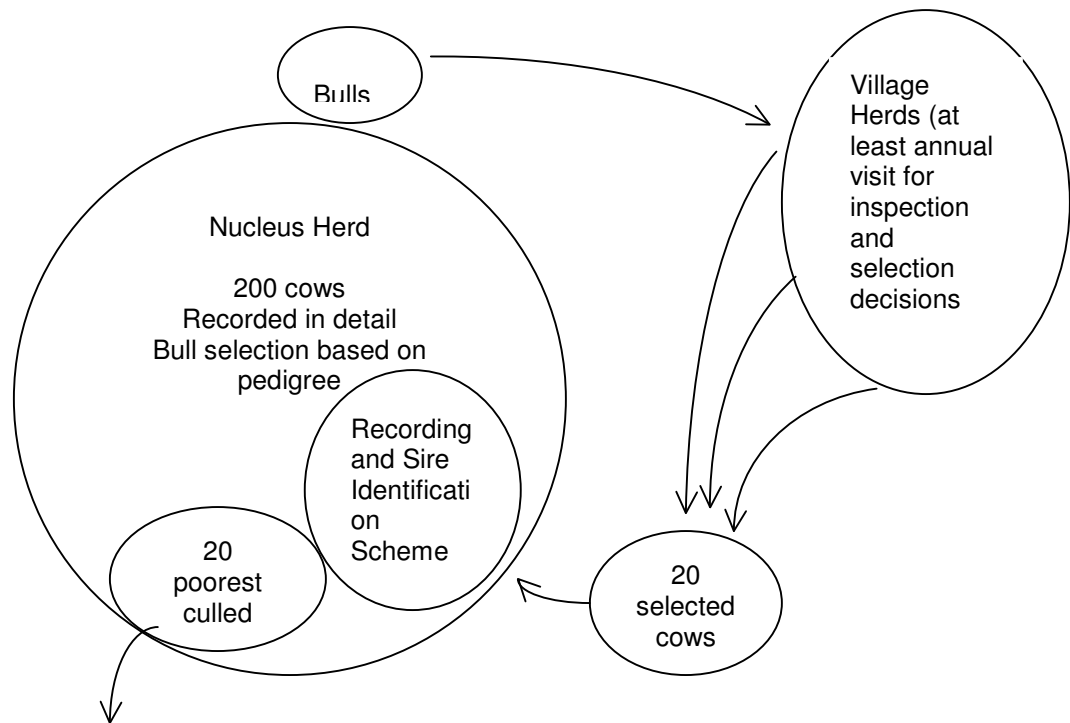


Figure 1. A schematic model of a proposed dispersed open nucleus scheme (adapted from Cunningham, 1979)

In the proposed nucleus breeding programme, as schematically presented in Figure 1, sires would be selected from the nucleus scheme. Cows would have to be selected from

production farms (large or small scale) to be part of the nucleus herd. These cows would continue being and producing in their original herds while at the same time identified as belonging to the nucleus herd. The production herds would remain distinct and independent and would be involved in a recording system that would be used in testing young animals.

At least 20 heifers would be selected per year into the nucleus scheme. In the scheme, the following will have to be done:

- (i) Identification of superior male genotypes, later to be used preferentially to maintain the elite status of the nucleus to sire the next generation of young bulls. Since in the early stages there would be no performance data from either the sisters (half or full sibs) or the daughters to the sons, their selection would be based on pedigree index. As the breeding programme progresses, the males would then be subjected to selection based on performance parameters like daily weight gain, feed intake, and their constitution. At maturity the young males could then start being utilized for testing mostly in the smallholder farms. This would not only facilitate generation reasonably more daughters per sire, but also introduce and enhance a more organized recording system within the smallholder sector. In order to avoid inbreeding and increase heterozygosity, a functioning bull exchange programme will have to be instituted.
- (ii) The breeding goal should be established by the immediate stakeholders in an interactive process.
- (iii) Recruiting superior female genotypes, which would be eligible for entry into the nucleus on completion of the testing phase. These superior females would be the dams of sires selected based on the ranking of their breeding values and examination and scoring of their conformation traits.
- (iv) Establish and institute a working incentive to all stakeholders. Since cattle theft is a major problem, one of the incentives in the scheme will be to assist farmers organize

theft control. A viable identification system with an animal trace-back system would assist very much in curbing down cattle theft.

All the effective breeding and selection activities would be confined within the nucleus scheme, which would be the source of male stock in the system. With good recording data could be generated from which genetic parameters and breeding values could be estimated leading to more effective selection.

Since a dispersed nucleus scheme depends on animals that belong to different farms such a programme would only function well with the full participation of the farmers and all institutions involved in animal production. This would help pool efforts, existing facilities and technical know-how together for the effective and efficient establishment of the programme.

The role of smallholder farmers and extension officers

This proposed model is designed as an on-farm development project with the community based smallholder farmer managing and running the scheme. Since smallholder farmers are the primary targets, their involvement will be ensured through consultative meetings from the planning phase. Farmers will contribute by letting their animals be utilized as part of the dispersed open nucleus herd and also through selling selected breeding stock to other farmers. In addition, extension officers will be closely involved in all aspects of the programme. The decision making process, preferably a farmer working committee is accompanied by the local extension officers and research staff from the University of Malawi, who monitor the programme, collect, process and analyse the data. The results of the recording will be made available to the farmers to support their management and decision making system. The data will be processed by the Animal Science Department of the University of Malawi, which is in direct contact with the farming committees. The recording system component of the programme just like the other components of the programme will be participatory. The farmers themselves should identify the traits of economic importance, which should be recorded and those that should be selected for. They should also identify the breeding goal and the aggregate genotype according to their

production system. The farmers should be involved in the measuring and the recording of the traits. Previous (Mwale et al., 1999; Mulume et al., 1999) and ongoing on-farm projects have demonstrated that farmers are most willing to collaborate in a recording scheme, if no counterproductive interventions take place and information and knowledge is made available to the livestock keeping farmer.

Expected benefits

The following are the envisaged benefits for this interactive process and technology sharing and transfer in the conservation of indigenous animal genetic resources in Malawi:

- ❑ Value adding to the indigenous animal genetic resources through estimation of breeding values.
- ❑ Sustainable utilization of indigenous animal genetic resources through intensified use.
- ❑ Utilization of indigenous animal breeding knowledge through incorporation of existing stock exchange systems or traditional breeding practices.
- ❑ Participatory conservation of indigenous farm animal genetic resources through interactive process among farmers and between stakeholders in- and outside of the community.

CONCLUSION

As Malawi Zebu have not been fully characterized and their unique attributes not fully known yet, one thing for sure is that they are well adapted and their competitiveness in the low input - low out system of Malawi is high. For this and also to exploit the unknown benefits, Malawi Zebu cattle need to be conserved. In systematic crossbreeding programmes for commercial bee production systems and also peri-urban dairy production, purebred Malawi Zebu will continue to provide the dam lines. This kind of crossbreeding requires pure lines of Malawi Zebu and could be one major use of the conservation of Malawi Zebu. The integration of Malawi Zebu cattle in the crop-

livestock mixed farming system would contribute to improving the general productivity of the ecosystem as the livestock and the crops depend on each other hence contributing to sustainable food security and poverty alleviation. Activating the farmers to get them organized and to provide enabling policies are a prerequisite to setting up a within breed selection and conservation programme for Malawi Zebu cattle. It is important to set up systems of getting reliable data on the genetic, phenotypic and economic performance of the reported genotypes of Malawi Zebu. There is need to improve infrastructure and define elaborate strategies for raising productivity and optimizing the production systems to ensure that the Malawi Zebu is conserved and utilized.

REFERENCES

Ambali, A. Nyirenda, J. and Chagunda M.G.G. (2001). Genetic characterization of the Malawi Zebu. Project Report submitted to SADC/FAO/UNDP Management of Farm Animal Genetic Resources in the SADC Region Project, Pretoria, Republic of South Africa.

Ayalew, W. 2000: Do smallholder farmers benefit more from crossbred (Somali x Anglo-Nubian) than from indigenous goats? Dissertation Univ. Goettingen, Cuvillier Verlag, Goettingen, 155pp

Bruns, E. (1995). Systems for recording structure and performance of animal populations under extensive tropical conditions. 2nd European Workshop on Advanced Biometrical Methods in Animal Breeding. Salzburg, 12-20 June, 1995.

Butterworth, M.H. and McNitt, J.I. (1994). The Malawi Zebu. World Animal Review. 49: 6-12.

Cunningham, P.E. (1995). Genetic diversity in domestic animals: Strategies for conservation and development. In Miler, R.H., Pursel, V.G., and Norman, H.D. (ed). American Society of Animal Science, Savoy, Illinois, USA.

Falconer, D. S. (1989). Introduction to Quantitative Genetics. Longman Scientific and Technical, Essex, England.

FAO, (2000). World Watch List for domestic animal diversity. Scherf, B.D. (ed). Food and Agriculture Organization, Rome, Italy.

ICLARM and GTZ (1991). The context of small-scale integrated agriculture-aquaculture systems in Africa: a case study of Malawi. ICLARM stud. Rev. 18, 320 p.

Jere, J. and Msiska, H.D. (2000). Current status on the management and utilization of Farm Animal Genetic Resources in Malawi. Paper presented at the Farm Animal Genetic Resources Workshop, Natural Resources College, Lilongwe, Malawi. March 2000.

Karugia, J.T., Mwai, O.A., Kaitho, R.J., Wollny, C.B.A., Drucker, A. and Rege, J.E.O. 2001: Economic analysis of cross-breeding programmes in sub-Saharan Africa: A conceptual framework and Kenyan case study. Animal Genetic Resources Research 2. ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 55

Lohuis, M. (1998). Establishment and use of nucleus herd schemes for genetic improvement in dairy cattle. Paper presented at Congress CAAB/CETA Convention, Saint-Hyacinthe, Quebec, August 30 - September 2, 1998. Available at: <http://www.aps.uoguelph.ca/~lohuism/CAAB/CAAB.html>. Accessed Dec. 2, 1999.

Malawi Government, (1996). Guide to Agricultural Production in Malawi. Agricultural Communication Branch, Ministry of Agriculture and Livestock Development, Lilongwe, Malawi. Pp 229.

Mulume, C.G., C.B.A. Wollny, J.W. Banda and R.K.D. Phoya 1999: Performance of local pigs under village conditions in the rural areas in Malawi. Proceedings of the 50th EAAP conference, 22-26 August 1999, Zurich, p. 288 (abstract)

Mwale, S.E., Wollny, C., Banda, J. W., Chagunda, M. G. G. and Bruns, E. (1999). Evaluation of Malawi Zebu and its crosses on smallholder dairy farms in Mzuzu, Northern Malawi. Tropentag 99, Humboldt University of Berlin, 14-15 October, 1999.

Nakhumwa, T.O., M.G.G. Chagunda, A.C.L. Safalaoh, and C. Mataya, (2000). Analysis of market potentials in the Northern Region of Malawi and preparation of a Business Plan for the Foundation of Improvement of Animal Health (FIAH), Mzuzu. Consultancy Report commissioned by GTZ, Lilongwe, Malawi.

NLDMP, (1998). Agricultural Sector Programme Support, Livestock component, Malawi Livestock Development Master Plan. Draft Final Report. Ministry of Agriculture and Irrigation. Lilongwe, Malawi.

Rege, J.E.O (1995). African livestock resources. A conceptual framework for characterizing the genetic diversity, Developing areas branch of the South Africa Society of Animal Science. Loskopdam, Pretoria, October 16 – 20, 1995.

Wollny, C. (1995). Breed improvement and future breeding strategies in livestock in Southern Africa. International Symposium of Animal Production through Breeding and Genetics. 10th-11th May, 1995, Harare, Zimbabwe, pp 61 - 70.

Wollny, C.B.A., A.G. Namwaza, T.S.W. Makamba and K. Kuettner 1998: The state of cattle breeding in Malawi. Animal Research and Development, **48**, 19-30

Wollny, C.B.A. 2001: The need to conserve farm animal genetic resources through community-based management in Africa: Should policy makers be concerned? Working paper: www.feem.it and www.cgiar.org/ilri/research/proj4/angr/article6-1.pdf

World Bank (1995) Malawi Agricultural sector memorandum: strategy options in the 1990s volume 1 and 2. Where published? Also see text: only once cited?